Introductory Astronomy

Homework 9: The Life of the Sun Not to be handed in. Homework solutions are posted already.

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040 qmult 00100 1 4 3 easy deducto-memory: life history of Sun

Extra keywords: Sunlife

1. The life history of our own star, the Sun, is known to us by:

    a) direct observations of all of its stages.
    b) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
    c) direct observations of its current stage plus observations of other stars in all their stages and modeling.
    d) modeling alone.
    e) sheer guesswork.

    SUGGESTED ANSWER: (c) We only directly observe the Sun in its current stage: i.e., the middle main sequence stage. The Sun has been there all of human history and will be there all of foreseeable human history.

    Wrong answers:
    e) "Sheer" and "guesswork" are correctly spelt anyway.

    Redaction: Jeffery, 2001jan01

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040 qmult 00200 1 1 5 easy memory: interstellar medium (ISM) defined 1

Extra keywords: CK-299,321, Sunlife

2. The interstellar medium (ISM) consists of:

    a) planets. b) molecular clouds only. c) stars. d) dust only. e) gas and dust.

    SUGGESTED ANSWER: (e)

    Wrong answers:
    a) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

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040 qmult 00310 1 4 1 easy deducto-memory: nebula defined

Extra keywords: CK-302,321, Sunlife

3. In modern astronomy, a nebula (plural nebulae) is a:

    a) cloud of a gas in space. b) large main sequence star. c) small main sequence star. d) bright star. e) young star.

    SUGGESTED ANSWER: (a) There are many kinds of nebulae: e.g., emission, dark, supernova remnant, reflection, and spiral nebulae: the last one is just a historical name since the spiral nebulae are spiral galaxies and not clouds, but before they were known to be galaxies were called nebulae because they looked like clouds to telescopic observers.

    Wrong answers:
    e) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

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040 qmult 00320 1 1 5 easy memory: molecular cloud and stars

Extra keywords: CK-321, Sunlife

4. The dense, cold component of the interstellar medium from which stars are believed to form is made of:

   a) H II (ionized hydrogen) regions. b) white dwarfs. c) protostars. d) Lyman-Alpha forests. e) molecular clouds.

   SUGGESTED ANSWER: (e) See Se-220. The molecular clouds don't always have to be giant molecular clouds: are they usually giant molecular clouds?

   Wrong answers:

   d) Some of these critters probably do end up helping to make stars.

   Redaction: Jeffery, 2001jan01

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040 qmult 00330 2 1 5 moderate memory: molecular cloud composition

Extra keywords: CK-300, Sunlife

5. The composition of molecular clouds in the interstellar medium is dominated by:

   a) carbon dioxide. b) molecular oxygen only. c) helium gas only. d) amino acids. e) molecular hydrogen and helium gas.

   SUGGESTED ANSWER: (e) Hydrogen and helium dominate the composition of the universe and a molecular cloud should have molecules. Zeilik p. 332 confirms that the hydrogen in molecular clouds is molecular hydrogen.

   Wrong answers:

   a) Carbon dioxide is an important tracer of molecular clouds, but it is a minority species.

   Redaction: Jeffery, 2001jan01

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040 qmult 00410 3 4 1 tough deducto-memory: molecular clouds and their dust

Extra keywords: Sunlife

6. Molecular clouds are probably about 1 per cent dust by mass.

   a) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   b) The dust is **VERY IMPORTANT** to these clouds. It is **COMPLETELY TRANSPARENT** to visible and ultraviolet light, and allows plenty of hard electromagnetic radiation into the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   c) The dust is **COMPLETELY UNIMPORTANT** to these clouds. True, the dust is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless,

there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.

d) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.

e) The presence of this dust is just coincidental. It just happens that where there is dust there are molecular clouds, and where there is no dust there arn't. Things could be entirely otherwise; they just arn't.

SUGGESTED ANSWER: (a) The problem discusses details that weren't and needn't be emphasized in class. But it shows who's thinking. See Se-212 and Zeilik p. 333, 337.

Wrong answers:

b) Hard radiation tends to break up molecules, whose bonds are not that robust. Thus the premise and conclusion of the answer disagree.

c) No, dust is important and molecular clouds and dust usually go together. But there can be dust without molecules and the reverse is probably true. But giant molecular clouds probably always have a lot of dust.

d) No, there arn't molecular clouds where one can see the star formation process in the visible: it seems to be always dust-shrouded.

e) Coincidences due happen, but modern science always suspects (and sometimes wrongly) that behind any seeming coincidence lies a a relationship.

Redaction: Jeffery, 2001jan01

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040 qmult 00420 2 4 3 moderate deducto-memory: molecular cloud dust described

Extra keywords: Sunlife

7. Interstellar dust probably varies widely in composition, size scale, and structure. But there some ideas about typical dust that are generally accepted.

a) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **VOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **NONVOLATILES** condense out on the cores.

b) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

c) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order 0.05 μm consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **NONVOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **VOLATILES** condense out on the cores.

d) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}$ m in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order 0.05 μm consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

e) The dust is found under sofas and on other untouched surfaces. It gets there by settling out the air. One often sees dust in air the reflecting bright sunlight.

SUGGESTED ANSWER: (c) See Zeilik p. 336–337.

Wrong answers:

a) Volatile and nonvolatile mix-up.
b) Volatile and nonvolatile mix-up. If it forms in a black hole, it doesn't get out. By the by, a scot is an archaic term for a payment or a tax derived from Scandinavian languages: it has nothing to do with laddies and lassies in kilts.
d) If it forms in a black hole, it doesn't get out.
e) This is terrestrial dust. I wonder what terrestrial dust is made of. Probably pretty various although some has to be silicates.

Redaction: Jeffery, 2001jan01

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040 qmult 00610 2 4 1 moderate deducto-memory: star formation triggers

Extra keywords: CK-302, Sunlife

8. Star formation in a dusty molecular cloud probably requires some triggering event to initiate the collapse to dense cores that will become stars. Two possible trigger mechanisms are:

a) **SUPERNOVAE** which compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
b) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
c) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **PROTOSTAR-PROTOSTAR COLLISIONS** which also compress the molecular clouds.
d) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.
e) **WHITE HOBBITS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.

SUGGESTED ANSWER: (a)

Wrong answers:

b) White dwarfs are miniscule compared to molecular clouds and would just run through them like beads of sand.

c) This is probably a pretty rare event and wouldn't compress clouds much.
e) Yes Tolkien has invaded space, but there are no white hobbits as far as I know.

Redaction: Jeffery, 2001jan01

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040 qmult 00710 2 4 2 moderate deducto-memory: free-fall molecular cloud
Extra keywords: Sunlife

9. In a **FREE-FALL** contraction of part of molecular cloud:

a) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.
b) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces are negligible in slowing the fall because it is a free-fall contraction.
c) the entire molecular cloud collapses to form a black hole.
d) the part collapses to form a black hole.
e) planetesimals collide and break apart.

SUGGESTED ANSWER: (b)

Wrong answers:
e) The planetesimals are a much later stage in solar system formation.

Redaction: Jeffery, 2001jan01

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040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife

10. A protostar is sometimes conveniently defined to be a:

a) star that can no longer burn hydrogen to produce thermal energy.
b) white dwarf.
c) star hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
d) molecular cloud that will become a star.
e) giant molecular cloud that will become a star.

SUGGESTED ANSWER: (c) Se-222, gives this definition and FK-450 implicitly agrees. He calls the protostar a prestellar object, but that seems too convoluted for me. But the term is used loosely in astronomy I think.

Wrong answers:
e) A white dwarf is at the far end of stellar evolution.

Redaction: Jeffery, 2001jan01

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040 qmult 00810 2 4 5 moderate deducto-memory: protostar contraction 1
Extra keywords: FK-451 agree with this, Sunlife

11. The contraction of a protostar is halted eventually by:

a) the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
b) the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.
c) the action of magnetic fields.
d) the action of the dynamo effect.
e) the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.

SUGGESTED ANSWER: (e)

Wrong answers:

a) Adding heat and contraction together should increase gas pressure.
b) The thermal energy generated by contraction and the increasing density of the gas do increase pressure, but they do not stop the contraction.

Redaction: Jeffery, 2001jan01

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040 qmult 01500 1 4 3 easy deducto-memory: disk defined
Extra keywords: Sunlife

12. "Let's play *Jeopardy*! For $100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles that orbit in the same direction some large astro-body in essentially circular orbits of varying radii."

What are ____________, Alex?

a) CDs b) planets c) disks d) satellites e) projectiles

SUGGESTED ANSWER: (c)

Wrong answers:

a) Compact disks are disks, but not the right kind of disk.

Redaction: Jeffery, 2001jan01

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041 qmult 01000 2 4 3 moderate deducto-memory: main sequence evolution
Extra keywords: Sun-question, Sunlife

13. During a star's **MAIN SEQUENCE LIFE**, the star is relatively unchanging. But, of course, it is actually changing slowly on the road to its demise. The key change is that:

a) carbon dioxide (CO_2) is being expelled by the star's wind.
b) molecular nitrogen (N_2) is being expelled by the star's wind.
c) hydrogen fuel is being exhausted in its core.
d) hydrogen fuel is being exhausted on its surface.
e) helium fuel is being exhausted in its core.

SUGGESTED ANSWER: (c)

Wrong answers:

e) Helium fuel is burnt during some post-main-sequence phases.

Redaction: Jeffery, 2001jan01

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041 qmult 01010 1 1 4 easy memory: main sequence longest phase
Extra keywords: CK-322-6, Sun-question, Sunlife

14. Most nuclear-burning stars are main sequence stars. The reason for this is that the main sequence phase of the nuclear-burning life of star of any mass is the:

a) shortest phase. b) most popular phase. c) wettest phase. d) longest phase.
e) darnest phase.

SUGGESTED ANSWER: (d) See CK-311

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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041 qmult 01030 2 4 4 mod. deducto-memory: early Sun luminosity
Extra keywords: Sun-question, Sunlife

15. At the time the Sun first became a main sequence star, its luminosity was probably ____________ than at present.

a) 30 % greater   b) 100 % greater   c) 50 times greater   d) 30 % lower   e) 100 % lower

SUGGESTED ANSWER: (d)

Wrong answers:
e) Now this doesn't seem very likely does it.

Redaction: Jeffery, 2001jan01

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042 qmult 00100 2 4 2 moderate deducto-memory: main sequence phase ends 1
Extra keywords: Sunlife

16. The end of a star's **MAIN SEQUENCE LIFE** (not its nuclear burning life) comes when it has:

a) exhausted the hydrogen fuel in its corona.   b) exhausted the hydrogen fuel in its core region.   c) become a white dwarf.   d) become a green dwarf.   e) exhausted the hydrogen fuel in its sunspots.

SUGGESTED ANSWER: (b)

Wrong answers:
e) Sunspots on other stars are usually called starspots. I once was a colleague of Doug Hall, a great starspot expert: he's now retired: it seems like a long time ago.

Redaction: Jeffery, 2001jan01

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042 qmult 00110 2 4 4 moderate deducto-memory: post-main sequence of Sun
Extra keywords: Sunlife

17. After the end of its main sequence lifetime the Sun will probably go through the following phases in order:

a) red giant, helium flash (a very short stage), horizontal branch star, green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
b) red giant, helium flash (a very short stage), horizontal branch star, jolly green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
c) red giant, helium flash (a very short stage), vertical branch star, second red giant (i.e., asymptotic red giant), cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
d) red giant, helium flash (a very short stage), horizontal branch star, second red giant (i.e., asymptotic red giant), planetary/pre-white dwarf, white dwarf, black dwarf (very far in the future).
e) red giant, Larry, Curly, Moe, black dwarf (very far in the future).

SUGGESTED ANSWER: (d) See Se-250–252 and Sh-152. Note only stars in the 0.4–3 $M_\odot$ range have a helium flash.

Wrong answers:
e) Larry, Curly, Moe—you get it—Larry, Curly, ...

Redaction: Jeffery, 2001jan01

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042 qmult 00300 2 4 3 moderate deducto-memory: horizontal branch star defined
Extra keywords: CK-327, Sh-149, Sunlife

18. Lower mass stars (i.e., those which had main sequence mass $\lesssim 8M_\odot$) when burning helium to carbon and oxygen in their **CORES** are called ____________ stars.

    a) red giant b) supergiant c) horizontal branch d) vertical branch e) oblique branch

SUGGESTED ANSWER: (c) Sh-149 limits the term to stars that don't become core-collapse supernovae which seems right to me.

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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042 qmult 00400 2 4 2 moderate deducto-memory: AGB star defined
Extra keywords: CK-328,346, FK-496,497, Sunlife

19. Lower mass stars (i.e., those which had main sequence mass $\lesssim 4M_\odot$) when burning helium to carbon and oxygen in a shell around an inert carbon-oxygen core, but before they have lost a lot of mass in helium shell flashes, are called ____________ stars.

    a) red dwarf b) asymptotic giant branch (AGB) c) horizontal branch d) vertical branch e) oblique branch

SUGGESTED ANSWER: (b) CK and FK disagree a bit about what happens to 4–$8M_\odot$ stars. But certainly what happens below $4M_\odot$ is clear.

Wrong answers:

e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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042 qmult 00410 1 4 3 easy deducto-memory: AGB Sun vaporizes Earth
Extra keywords: Sunlife

20. If in its AGB (asymptotic red giant) phase (or 2nd red giant phase), the Sun has expanded and enveloped the Earth, the Earth will:

    a) very quickly collapse to a black hole.
    b) become a red giant star.
    c) spiral into the deeper layers of the Sun because of the drag forces of the Sun's outer layers. There the Earth will be totally vaporized. "So the glory of this world passes away": *Sic transit gloria mundi.*
    d) gain escape velocity and be ejected from the solar system because of the drag forces of the Sun's outer layers.
    e) implode to form a protostar.

SUGGESTED ANSWER: (c) Zeilik p. 359 gives the Earth only about 200 years of survival after envelopment.

I once carried on a conversation in Latin: "E pluribus unum", "tempus fugit", "natura nonsaltum", "O tempores, O mores", "in vino veritas".

Wrong answers:

a) We havn't discussed black holes, but I don't think this answer would seem plausible compared to the others.

b) This is what the Sun is doing, not the Earth.
d) Drag forces slow down, they don't accelerate. They always oppose motion.
e) The Earth is much too small to become a protostar and why would it do this.

Redaction: Jeffery, 2001jan01

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042 qmult 00500 2 4 2 moderate deducto-memory: helium shell flash defined
Extra keywords: CK-328,346, FK-493, Sunlife

21. "Let's play *Jeopardy*! For $100, the answer is: These short-time scale episodes of explosive helium shell burning in late stellar evolution eject material that become planetary nebulae."

What are ____________, Alex?

a) hydrogen shell flashes b) helium shell flashes c) supernovae d) hypernovae e) novae

SUGGESTED ANSWER: (b)

Wrong answers:
a) The answer say helium shell burning

Redaction: Jeffery, 2001jan01

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042 qmult 00600 1 4 4 easy deducto-memory: planetary nebula defined
Extra keywords: CK-329,346 FK-493, Sunlife

22. A planetary nebula is:

a) a cloudy **planet**.
b) a cloud that will coalesce into a **planet**.
c) a shell of gas thrown off by a dying star before it becomes a **protostar**.
d) a shell of gas thrown off by a dying star before it becomes a **white dwarf**.
e) a shell of gas thrown off by a dying star before it becomes a **galaxy**.

SUGGESTED ANSWER: (d)

Wrong answers:
a) This answer should be really out of it.

Redaction: Jeffery, 2001jan01

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043 qmult 00100 1 4 1 easy deducto-memory: white dwarf defined
Extra keywords: CK-346,347-5, Sunlife

23. White dwarfs are:

a) the compact remnants of stars. They are **NOT** burning nuclear fuel. They are **COOLING DOWN** forever.
b) giant red stars.
c) the compact remnants of stars. They are **STILL** burning nuclear fuel.
d) the compact remnants of stars. They are **NOT** burning nuclear fuel. But they are **HEATING UP** forever.
e) the compact remnants of stars. They are **NOT** burning nuclear fuel. They have **NEVER** been observed: they are merely predicted theoretically.

SUGGESTED ANSWER: (a)

Wrong answers:

e) They have to been observed.

Redaction: Jeffery, 2001jan01

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043 qmult 00300 2 1 4 moderate memory: black dwarf defined

Extra keywords: Sunlife

24. A black dwarf is:

a) a black hole.
b) a protostar hidden in a molecular cloud.
c) a protostar after emerging from its cocoon of gas and dust.
d) what a white dwarf becomes when it has cooled off to near absolute zero temperature.
e) a shell of gas thrown off by a dying star before it becomes a galaxy.

SUGGESTED ANSWER: (d)

Wrong answers:
e) The shell is a planetary nebula and a dying star doesn't become a galaxy.

Redaction: Jeffery, 2001jan01